Multiple spectral peaks filtering through nonlinear polarization rotation with molecular gas absorbed-femtosecond lasers

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1. Introduction

Optical frequency combs are very useful sources for high resolution molecular spectroscopy. It can be desirable to use frequency combs which have high power per each comb mode to measure the meaningful signals with high signal-to-noise ratio.

Recently reported spectral peaking phenomenon which can obtain peak mode intervals with nm levels (~100 GHz) can be attractive [1,2] to make freely controllable high power comb modes. The spectral peaking is recently reported phenomenon that narrow spectral dips of optical pulses turn into sharp spectral peaks as propagating through nonlinear optical fibers. The Signal-to-Background Ratio (SBR) of the spectral peaking modes with ~3 nm nearly periodical spacing was reported as 9.2 dB which were generated from CH_4 gas-absorbed nearly periodical spectral dips at 1650 nm center wavelength [2]. However, it is worthwhile to improve the SBR for highly sensitive spectroscopy applications.

In this paper, we investigated nonlinear polarization rotation (NPR)-based spectral peaking mode filtering from CH_4-absorbed spectrum of mode-locked Er-fiber lasers. We introduced a NPR-based filtering system to suppress broadband background pedestal in a previous spectral peaking experimental setup [2].

2. Experimental results

Figure 1 shows the schematic of the NPR-based spectral peaking mode filtering method. A carbon nanotube saturable absorber-based mode-locked Er-fiber laser with 50 MHz repetition rate was used. To access to CH_4 absorption spectrum, the 1556 nm center wavelength was shifted to 1650 nm through a 5 m polarization-maintaining single-mode fiber with 99 mW input power. Pulse duration was preserved to 200 fs, thanks to Raman-shifted soliton pulse generation through the fiber. The soliton pulses were passed through a CH_4 gas cell, and nearly periodical spectral dips were generated. After blocking the 1556 nm residual components using a long-pass filter, the soliton pulses experienced the spectral peaking phenomenon through a 5 m normally dispersive highly nonlinear fiber (ND-HNLF). The spectral peaking signals were generated with broadband background pedestal (Fig. 2 (a)).

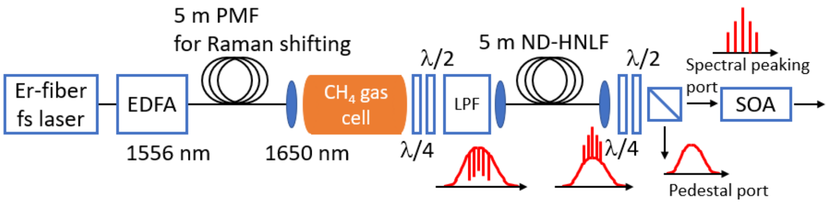

Fig. 1. Schematic of the NPR-based spectral peaking mode filtering. SOA, semiconductor optical amplifier.

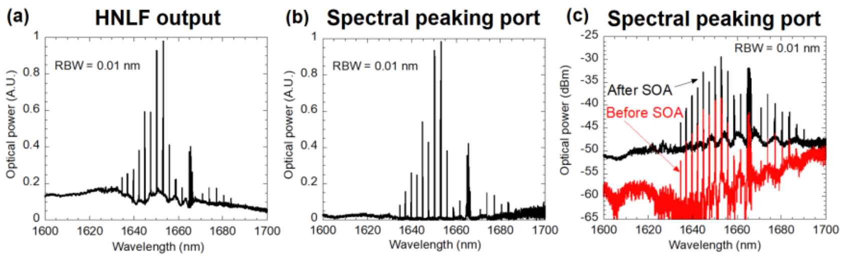

Fig. 2. Optical spectra at various ports in Fig. 1. (a) HNLF output, (b, c) spectral peaking port.

To separate the signals from the broadband pedestal, nonlinear polarization rotation was used. As spectral peak signals and broadband pedestal experience different nonlinear phase shift and polarization rotation, the two components can be separated through a polarizing beam splitter (PBS) and waveplates. The SBR of the spectral peaking signals before the NPR-based filtering was 9 dB (Fig. 2 (a)). After filtering them through the PBS, ~20 dB SBR was obtained at one port (Fig. 2 (b)). Most of the optical power was concentrated at the broadband background pedestal, so the pedestal which intensively experienced the nonlinear polarization rotation mainly moved to the other port, and the SBR was improved from 9 dB to ~20 dB. After amplification by a semiconductor optical amplifier (SOA), the peak signals were amplified by ~10 dB, and the SBR was more improved thanks to the saturation of the broadband pedestals (Fig. 2 (c)).

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3. References

[1] N. Nishizawa and M. Yamanaka, “Periodical spectral peaking on optical pulses,” Optica **7**, 1089-1092 (2020).
[2] N. Nishizawa and M. Yamanaka, “Characteristics of spectral peaking in optical fibers,” Opt. Express **29**, 42876-42886 (2021).

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